Lab Guide

Muon veto systems based on plastic scintillators

Objectives

1. Understand the principles of muon detection using plastic scintillators.
2. Learn to set up and calibrate a Silicon Photomultiplier (SiPM) for detecting scintillation light.
3. Record and analyse the data to identify muon events.

Equipment

- Plastic Scintillators + Wavelength shifting (WLS) optical fibers
- Silicon Photomultipliers (SiPMs)
- Data Acquisition System (DAQ)
- Trigger system
- Power distributor
- Router
- Computer with Analysis Software
- Signal Cables and Connectors

Introduction

Muon veto systems act as an active shield to tag any muon-induced activity in particle detection experiments. In this laboratory practical, students will learn how to build and use such a system. They will operate a setup consisting of plastic scintillators coupled to silicon photomultipliers (SiPMs) through wavelength shifting fibers. The practice will cover fundamental aspects of SiPMs as light detectors, as well as techniques for muon detection using plastic scintillators. Students will acquire and analyse data to estimate the muon detection efficiency of the experimental setup.

Procedure

1. Setup

I. **Assemble the Detector:**

   - Connect the WLS fiber to the SiPM. Use the optical adapter to ensure proper alignment between the two and apply optical grease to ensure a good connection.
   - Connect the DAQ system to the Controller Box using the three UTP cables. Guide yourself using the names on the labels.

II. **Power Supply and Net connection:**

   - Power up the controller box using the interlock cable and wait for one minute until the router is up and running.

- To be able to connect to the router or the DAQ system, connect to the wifi network “MuonVeto”. The users and IP address are:
    1. Router: root@10.0.0.1
    2. DAQ: root@10.0.0.101

III. **Data Acquisition Software:**

- Download the corresponding python scripts/notebooks to analyse the data.

2. Calibration

Before muon signals can be measured, it is necessary to calibrate the SiPMs. To do this, their breakdown voltage value must be obtained. One way to obtain this value is to obtain the gain or photon equivalent (PE) peak of the SIPM as a function of the operating voltage. From this curve it can be estimated for which voltage value the gain or equivalent photon peak becomes zero, this voltage value corresponds to the breakdown voltage.

I. **Photon Equivalent Peak:**

- Measure the dark count rate as function of the discrimination threshold.
- From the data, obtain the PE peak in DAC values.

II. **Breakdown Voltage:**

- Obtain the PE peak of the SiPM for several voltage settings.
- Estimate the voltage setting where the PE peak becomes zero. This value will correspond to the breakdown voltage of the SiPM.
- Set the operating voltage of the SiPM to the breakdown voltage + 3.5V.

III. Comparator Threshold:

- Measure the dark count rate as function of the discrimination threshold.
- Discuss which would be the best discrimination threshold to detect muons and set this value in the DAQ system.

3. Data Collection

- Start the DAQ system to record muon event data.
- Let the system run for a specified period to collect enough data for analysis.

4. Data Analysis

- Use the analysis software to identify muon events in the recorded data.
- Calculate the muon detection efficiency of the scintillator.
- Discuss about the results.

References

1. Particle Detectors: Fundamentals and Applications
2. SiPM / MPPC
3. Design, upgrade and characterization of the silicon photomultiplier front-end for the AMIGA detector at the Pierre Auger Observatory
4. Design and implementation of the AMIGA embedded system for particle detectors
5. Muon Counting using Silicon Photomultipliers in the AMIGA detector of the Pierre Auger Observatory